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November 12, 2019

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, D.C., 20554

Re: Unlicensed Use of the 6 GHz Band, ET Docket No. 18-295; Expanding Flexible Use in
Mid-Band Spectrum Between 3.7 and 24 GHz, GN Docket No. 17-183

Dear Ms. Dortch:

AT&T Services, Inc., on behalf of the subsidiaries and affiliates of AT&T Inc. (collectively, “AT&T”), provides the following *ex parte* letter to further explain why automated frequency coordination (“AFC”) is essential to enable unlicensed radio local area network (“RLAN”) devices to protect Fixed Service (“FS”) microwave incumbents from harmful interference in the 6 GHz band. Among other things, AT&T responds in this letter to a recent *ex parte* filing by Hewlett Packard Enterprise (“HPE”) and Federated Wireless (“Federated”), which demonstrates that AFC is viable and, more importantly, that universal AFC requirements should be an absolute precondition for any new RLAN use of 6 GHz spectrum.¹ AT&T also responds to a recent *ex parte* filing by the Wi-Fi Alliance (“WFA”)²—which makes the flawed argument that AFC is unnecessary—by providing, in Exhibit A, real world examples of potential interference to AT&T FS links from foreseeable RLAN device use and providing, in Exhibit B, a description of how fade margin is engineered for FS links. These analyses demonstrate that the current proposals of RLAN advocates for AFC-free “very low power” (“VLP”) and “low power indoor” (“LPI”) operation will not protect primary licensees in the 6 GHz band.³

¹ Letter from Paul Margie, Counsel to Hewlett Packard Enterprise, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed Oct. 3, 2019) (“HPE/Federated *Ex Parte*”); “Automated Frequency Coordination (AFC) Prototype Demonstration,” Attachment to HPE/Federated *Ex Parte* (dated Oct. 1, 2019) (“*AFC Study*”).

² Letter from Alex Roytblat, Senior Director of Regulatory Affairs, Wi-Fi Alliance, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed Oct. 16, 2019) (“WFA *Ex Parte*”).

³ See, e.g., Letter from Apple Inc., Broadcom Inc., Cisco Systems Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Inc., Microsoft Corporation, and Qualcomm Incorporated (“RLAN Proponents”), to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (dated July 2, 2019) (“*RLAN VLP Letter*” or, for Attachment, “*RLAN VLP Study*”); Letter from RLAN Proponents and Ruckus Networks, a Business Segment of CommScope, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (dated July 5, 2019) (“*RLAN LPI Letter*” or, for Attachment, “*RLAN LADWP Study*”).

Background. AT&T is one of the country’s largest users of Wi-Fi technology and supports the rational introduction of unlicensed technologies into new bands on a non-interference basis. However, the Commission cannot and should not, in the 6 GHz environment, shortchange incumbent users’ grave and demonstrably legitimate concerns regarding harmful interference due to the RLAN industry’s irrational exuberance to market new devices hastily rather than thoughtfully. The RLAN advocates have fatally failed to make a technical showing of non-interference—their studies have been refuted on the record via several *ex parte* filings by multiple parties, including CTIA and the Fixed Wireless Communications Coalition (“FWCC”).⁴ As CTIA pointedly observed, the technical studies submitted by RLAN proponents to date rely on “unreasonable assumptions, unsuitable methodologies, and unsupported conclusions.”⁵

Indeed, one RLAN advocate has now made the startling (but accurate) admission that “[t]he parties also appear in agreement that . . . interference events *inevitably* will occur for some fixed links.”⁶ This admission should have led to an acknowledgment that robust and well tested AFC systems must govern *all* RLAN devices to avoid otherwise “inevitable” interference and to help mitigate interference events that do occur.⁷ Instead, the RLAN advocates’ head-in-the-sand viewpoint appears to remain that, because “the statistical probability of these events is low

⁴ See, e.g., Letter from Jennifer L. Oberhausen, Director, Regulatory Affairs, CTIA, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed Oct. 22, 2019) (“CTIA *Ex Parte*”); Letter from Donald J. Evans and Mitchell Lazarus, Counsel to FWCC, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed Oct. 31, 2019) (“FWCC *Ex Parte*”); Letter from Donald J. Evans and Mitchell Lazarus, Counsel to FWCC, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed Sept. 26, 2019); Letter from Donald J. Evans and Mitchell Lazarus, Counsel to FWCC, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed Sept. 13, 2019); Letter from Donald J. Evans and Mitchell Lazarus, Counsel to FWCC, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed Sept. 3, 2019); Letter from Donald J. Evans and Mitchell Lazarus, Counsel to FWCC, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed Aug. 22, 2019) (“FWCC Aug. 22, 2019 *Ex Parte*”); Letter from Donald J. Evans and Mitchell Lazarus, Counsel to FWCC, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed Sept. 3, 2019); Letter from Donald J. Evans and Mitchell Lazarus, Counsel to FWCC, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 at 4 (filed July 25, 2019); Letter from Donald J. Evans and Mitchell Lazarus, Counsel to FWCC, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 (filed May 29, 2019).

⁵ CTIA *Ex Parte* at 1.

⁶ Letter from Bruce Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 18-295 at 3-5 (filed Nov. 1, 2019) (“Boeing *Ex Parte*”) (emphasis added).

⁷ See, e.g., FWCC Aug. 22, 2019 *Ex Parte* at 7; AT&T also reiterates its full-throated support of the unanimous call of 6 GHz incumbents that whatever AFC system is ultimately deployed must be exceptionally robust and rigorously tested—in the lab and in the field—before being allowed to operate live. See, e.g., Letter from Michael P. Goggin, AT&T Services, Inc. to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket 18-295 (Aug. 8, 2019) (“AT&T Aug. 8, 2019 *Ex Parte*”); Letter from Public Safety and Critical Infrastructure Entities and Organizations to Hon. Ajit Pai, Chairman, Federal Communications Commission, ET Docket 18-295 (Nov. 8, 2019) (representing 11 Public Safety and Critical Infrastructure Industry trade associations and nearly 60 entities).

(although how low is in dispute),”⁸ the Federal Communications Commission (“Commission” or “FCC”) can simply ignore them, or that FS users should be responsible for implementing costly technology upgrades to better absorb RLAN device interference.⁹

To try to distract the Commission from the appalling prospect of “inevitable” harmful interference, RLAN proponents resort to deceptively benign misnomers. For example, RLAN proponents refer to “low power” and “very low power” devices. But the reality is that their proposed “low power” levels are up to 30 dBm EIRP,¹⁰ the same power limit used for handsets in a licensed service like AWS.¹¹

Moreover, the probability of harmful interference is not “low” and is not confined to “corner cases” or worst-case scenarios—the examples in Exhibit A of harmful interference to operations in AT&T’s FS portfolio were readily identified after reviewing the specifics of only a few dozen (out of thousands) of licensed facilities. Finally, under the Commission’s rules, the responsibility of interference avoidance and remediation plainly falls on the unlicensed potential/actual interferers—here, the operators of RLAN devices—and not on the licensed incumbents.¹²

The AFC Study demonstrates that AFC is workable and absolutely necessary. The recently filed HPE/Federated *AFC Study*, which details examples of AFC coordination data and timing, demonstrates that AFC is absolutely needed to avoid harmful interference to FS links. The *AFC Study*, for example, shows the coordination results for an RLAN device in New York City at the intersection of Crosby St. and Prince St. in Lower Manhattan.¹³ Among other problems, those coordination results show several microwave facilities where interference would plainly result

⁸ Boeing *Ex Parte* at 3-5.

⁹ *Id.* (suggesting it should be the responsibility of FS licensees to implement adaptive coding and modulation to overcome RLAN device-induced interference).

¹⁰ *Unlicensed Use of the 6 GHz Band*, Notice of Proposed Rulemaking, FCC 18-147, ET Docket No. 18-295 at App. B, proposed rule §15.407 (rel. Oct. 24, 2018) (“6 GHz NPRM”).

¹¹ See 47 C.F.R. §27.50(d)(4).

¹² 47 C.F.R. §15.5(b) (stating that “[o]peration of an intentional . . . radiator [under Part 15] is subject to the condition[] that no harmful interference is caused.”). Notably, when considering the introduction of Multichannel Video and Data Distribution Services (“MVDDS”) into the Direct Broadcast Satellite (“DBS”) band, the Commission determined that MVDDS—a licensed service with higher status than unlicensed RLAN devices—would be deemed to cause “harmful interference” to DBS if the outage time for DBS service at a receiver location increased by 10% or more. Here, as discussed in Exhibit B, the magnitude of the increase in outage times for FS, which includes critical industries and public safety services, is far greater even though RLAN devices should have no right to cause any harmful interference. See, e.g., *Amendment of the Parts 2 and 25 of the Commission’s Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range*, Report and Order, 17 FCC Rcd 9614, 9634-51 (2002). Notably, in the event of harmful interference, MVDDS licensees—not DBS operators—are required to mitigate the interference. *Id.* at 9651-55.

¹³ Given the building heights at that location, the assumption of a 100m (±3m) RLAN device operating height appears reasonable. See *AFC Study* at 13.

from the RLAN device's operation—WQHC635, which shows an I/N of 19 dB, and KBX88, which shows an I/N of 9 dB—both of which are Public Safety pool microwave authorizations.¹⁴ Using a rational FS protection level,¹⁵ if RLAN devices' use of channels were not regulated by an AFC, the RLAN device in this example would create interfering signals at the receiver more than a thousand times (31 dB) above the acceptable margin for WQHC635 and more than a hundred times (21 dB) above the acceptable margin for KBX88. Even worse, the assumptions for the example include the RLAN device transmitting at an EIRP of 20 dBm, which is one-tenth of the maximum proposed power for 6 GHz.¹⁶ At full power, the RLAN device would exceed the acceptable margin for WQHC635 by more than ten thousand times (41 dB).¹⁷

The *AFC Study* is also easily extrapolated to show why AFC must be required even for VLP and LPI devices. In the example discussed, the I/Ns range up to 31 dB above the margin for an RLAN device transmitting at 20 dBm EIRP. At WFA's requested limit of 14 dBm for VLP devices,¹⁸ the New York City RLAN device in the HPE/Federated example *still* would be over a hundred times (25 dB) the threshold for harmful interference. Although that example assumes no signal power reduction from indoor operation, VLP devices are not subject to an indoor-only operating condition, so that assumption is, in fact, appropriate.

Real world examples from AT&T's FS portfolio show realistic VLP and LPI deployments can cause harmful interference. AT&T's Exhibit A shows that, as much as RLAN proponents attempt to discount interference scenarios outside a statistical mean as “corner cases,” those situations exist in the real world and pose significant threats of harmful interference to operating FS links.¹⁹ Specifically, AT&T's Exhibit A analyzes the impact of RLAN deployments on FS links currently in operation supporting vital communications in AT&T's network. Based on

¹⁴ WQHC635 is licensed to the City of New York in the “MW – Microwave Public Safety Pool” radio service, *see* <https://wireless2.fcc.gov/UlsApp/UlsSearch/license.jsp?licKey=2923833>. KBX88 is licensed to the New Jersey Turnpike Authority in the “MW – Microwave Public Safety Pool” radio service, *see* <https://wireless2.fcc.gov/UlsApp/UlsSearch/license.jsp?licKey=956889>.

¹⁵ *See* AT&T Aug. 8, 2019 *Ex Parte* at 3 n.6 (filed Aug. 8, 2019) (explaining that an FS protection level of -12 dB I/N is reasonable because, although typical FS-to-FS protection is -6 dB I/N, secondary services like RLAN devices should be accommodated at a lower threshold (3 dB less) and that an additional 3 dB margin for aggregate effects should be added).

¹⁶ 6 GHz NPRM at App. B, proposed rule §15.407.

¹⁷ The example for the FCC building in Washington, D.C., also show I/Ns that are troublesome, even at a reduced operating power—*e.g.*, 12 dB for WQQM525, 11 dB for WQVB790. *AFC Study* at 16. These examples assume 0 dB building entry loss, which is entirely reasonable for outdoor locations such as patios or roof decks. But, even if significantly greater building entry loss is assumed, the RLAN devices in these examples would still interfere with several FS links in the absence of AFC governance. *Id.*

¹⁸ *RLAN VLP Study* at 2.

¹⁹ With due consideration to FWCC's observation that when there are “deploy[ed] devices in the hundreds of millions,” the number of devices “will make rare occurrences commonplace,” the situations cited by AT&T are neither worst case, nor the only examples of these types of situations in AT&T's 6 GHz network. FWCC *Ex Parte* at 3. AT&T, in fact, reviewed only a tiny fraction of its links to find the particular examples used in Exhibit A.

ULS data and visual and topographic surveys of surrounding areas,²⁰ AT&T identified locations where operation of RLAN devices would be predictable—in houses, in office buildings, and at a local business—and then calculated their impact on a victim FS receiver.

To determine the potential impact of an RLAN device on the victim FS link, AT&T initially calculates an “acceptable” RLAN device EIRP limit and then quantifies potential harmful interference based on operation at the proposed 30 dBm indoor power limit. All of the calculations are based upon the actual geometry of the transmission sources and the receiver, as well as the antenna parameters for each. The assumptions used by AT&T are conservative:

- Although AT&T believes -12 dB is the appropriate I/N for FS protection, AT&T also calculated the impacts using I/N values of -9 dB and -6 dB.
- AT&T used free space propagation because a visual inspection of the examples shows clear, unobstructed line-of-sight between the RLAN device and victim receiver.
- Even though CTIA and FWCC have correctly noted that polarization mismatch cannot be guaranteed between RLAN devices and FS links because the antennas on RLAN devices are repositionable, AT&T nonetheless added a 3 dB of attenuation to the interfering RLAN device’s signal due to polarization mismatch.
- AT&T further factored in 3 dB of attenuation for bandwidth mismatch—compensating for the fact that the RLAN device’s power is dispersed over 80 MHz, whereas the victim FS links generally have bandwidths of 30 MHz.²¹ While RLAN proponents have suggested a larger bandwidth mismatch adjustment is appropriate, RLAN proponents have ignored the fact that FS receivers do not have “brick wall” filters—while they employ filters to reject out-of-band emissions from undesired sources, some amount of noise from adjacent channels reaches the receiver.²²
- AT&T’s calculations also adjust for the antenna pattern mismatch given the angle of the RLAN device’s signal relative to the FS receiver location. In these examples, that results in near-zero attenuation because most RLAN devices have little loss of gain as a result of the azimuth difference.

Importantly, AT&T’s examples also properly apply building entry loss (“BEL”). Prior analyses have oversimplified BEL into a single value—as CTIA noted, “ITU-R Rec. P.2109-0 on BEL requires sharing studies to use the full distribution, not a single level of loss.”²³ In simple terms,

²⁰ Although AT&T’s own data is consistent with the ULS data, using ULS data and public sources permits the results to be replicated by other interested parties.

²¹ FWCC Aug. 22, 2019 *Ex Parte* at 10-11.

²² *Id.*

²³ CTIA *Ex Parte* at Attachment, p. 15. RLAN advocates’ extensive mischaracterizations of BEL have been tabulated by the FWCC, *see* FWCC Aug. 22, 2019 *Ex Parte* at 6, Table 1.

ITU-R policies recognize that BEL is dependent upon a variety of factors, including where a user might position the transmitting device relative to building materials with differing attenuations (*i.e.*, in front of a window, as opposed to behind a concrete wall). ITU-R Rec P.2109 also recognizes two different types of buildings—thermally-efficient buildings (which typically use metalized glass windows and foil-backed insulation that provide better radiofrequency shielding) and traditional buildings. The ITU-R model also recognizes that the elevation angle—the angle at which the transmission intersects the building skin—plays a large role in attenuation. At the 6.5 GHz frequencies at issue and a zero-elevation angle, the BEL distribution is shown below:

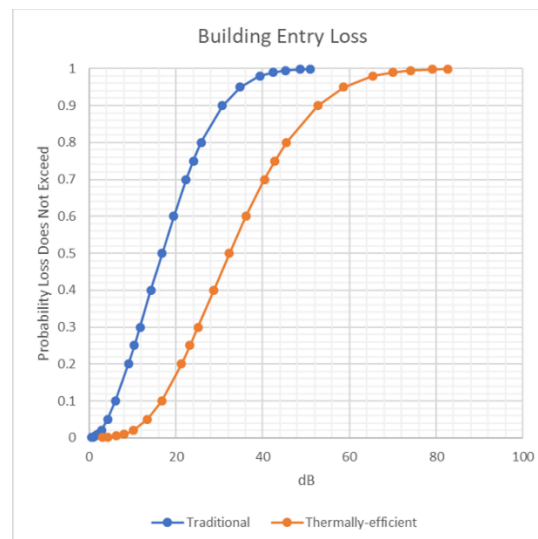


Figure 1: Probability Building Entry Loss Does Not Exceed, ITU-R P.2109

Because the P.2109 curves are designed to assist carriers in determining the certainty of indoor coverage from wireless networks, this chart models the probability that loss *does not exceed* the values on the horizontal axis. In other words, using the chart data, a carrier can determine the percentage chance that its signal will be *no less* than a certain threshold indoors. For purposes of this analysis, however, the question is how much the indoor signal is attenuated by the building materials—our analysis requires the probability that the loss *is at least*, rather than *does not exceed*, a particular value. For this reason, for purposes of this analysis, a higher percentage is not as protective to FS incumbents as a lower percentage—the 75% probability shown on the chart that attenuation from a traditional building does not exceed 24 dB is, for our purposes, only a 25% percent probability that the attenuation is 24 dB or more. In practical terms, that means if you assumed that building attenuation is 24 dB, 75% of the time the RLAN device would produce signals in excess of the modeled result. Taken to an extreme, the only way to ensure certainty (100%) in an interference analysis is to assume BEL is zero.

Because BEL is a distribution, not a single value, the interference cases shown in AT&T's Exhibit A reflect probabilities, not a simple binary value. AT&T has provided five examples of FS links and, in one of those cases, modeled two different RLAN-device interferers. All of the

examples show a very high potential for the RLAN device to cause interference to the FS incumbent.

For example, one of AT&T's scenarios considers interference to WQCX429, part of a 23.1 km path in Arizona. Due to ground elevation changes, there are residences that intersect with the main beam of the receiver. The geometry for the scenario is shown below:

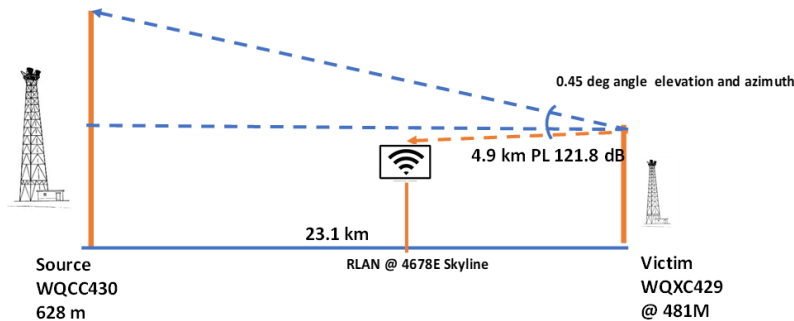


Figure 2: FS Link and RLAN Interference Geometry

Using this configuration and FS link data from ULS, AT&T derived the following probability-based summary of the potential impact of the RLAN device on AT&T's receiver:

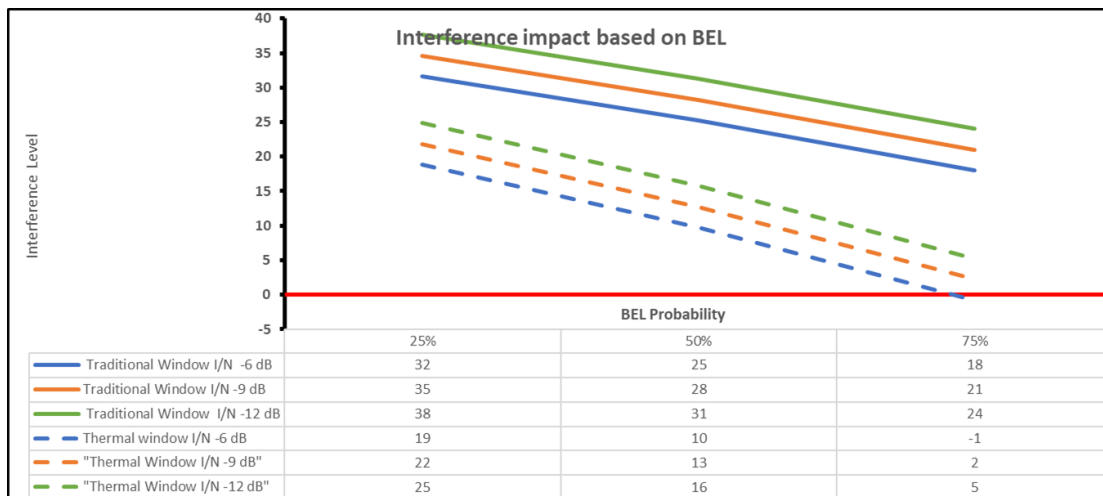


Figure 3: RLAN Interference Impact Based on BEL Probability

Thus, for a traditional construction—which would apply to most residential dwellings—and using AT&T's -12 dB I/N objective, there is a 25% probability that the receiver would experience interference greater than 38 dB above the acceptable limit and a 75% probability it would experience interference power at least 24 dB above the limit.

In sum, AT&T's attachment looks at a number of different real-world examples, and the results are extremely troubling. The scenarios include an RLAN device operating in close proximity to

the FS victim receiver—a common situation with FS links backhauling traffic from rural cell sites—and a situation that results in a short distance to the victim receiver with a high discrimination angle. Other examples consider an RLAN device operating relatively far from the FS receiver, but in situations where the terrain causes the RLAN device to be in or close to the main beam. Each of the modeled probability scenarios shows high percentage chances that the RLAN devices will cause harmful interference to the victim FS receiver.

The scenario depicted in the WQXC429 example is not uncommon in AT&T's network. AT&T uses 6 GHz microwave, among other things, to backhaul traffic from more rural sites to more urbanized areas where fiber connectivity is available. Because of the lengths of these paths, even with tight receiver antenna directionality, the main beam can intersect ground level where residences and businesses are located. And it is entirely foreseeable that the use cases for RLAN devices would include those types of places. Indeed, AT&T's examples show a case where a residence has a detached garage that has power—it is foreseeable that the homeowner might position an RLAN device to maximize coverage in the direction of the outbuilding, which would happen to be in the direction of the FS receiver.

Fade margin is engineered into FS links based on calculations specifically designed to reach certain reliability levels. The RLAN advocates in this proceeding continue to insist that any incidental added noise caused by RLAN operation will only have a minor impact on FS links because it will result in a small reduction in the link's fade margin. This specious argument relies on the incorrect premise that fade margin is somehow “excess” protection. As the RLAN proponents surely know, fade margin is specifically engineered on a link-by-link basis to meet certain reliability criteria—a process that is costly and therefore not undertaken without demonstrated need. AT&T's Exhibit B shows the calculations used to engineer fade margin into FS links, as well as analyzing the impact on reliability of introducing interfering RLAN device signals.

As discussed in Exhibit B, fade margin is *not* some protective cloak spontaneously created when an FS link is designed whether it is needed or not, but rather an intentional product of well-known and time-tested engineering calculations. Exhibit B notes, for example, that there are three types of fading—rain, dispersive, and flat—with flat fading being the predominant source of outages for modern FS radio systems.²⁴ Importantly, because fading on each direction of a two-way (frequency duplex) FS link is uncorrelated for dispersive and flat fading in the 6 GHz band, ANSI TIA-10 computes total outage for a path as the sum of rain fade outage plus two times the one-way dispersive and flat fading times.

Exhibit B discusses in detail how received interference can reduce the flat fade margin and thereby increase outage times. At the same time, Exhibit B recognizes that the use of space diversity can change the relationship between margin changes and outage times, because space diversity mitigates, to a degree, fading conditions. Ultimately, Exhibit B derives a table, shown

²⁴ Outages from dispersive fading can largely be controlled through the use of adaptive equalizers in the radio receiver, which are widely deployed.

below, with separate results for systems using space diversity and systems without, that shows the percentage increase in outage times resulting from changes to the fade margin (ΔFM).

No Diversity			Space Diversity		
ΔFM [dB]	One-way	Total	ΔFM [dB]	One-way	Total
1	1.26	1.13	1	1.58	1.29
2	1.58	1.29	2	2.51	1.76
3	2.00	1.50	3	3.98	2.49
5	3.16	2.08	5	10.00	5.50
7	5.01	3.01	7	25.12	13.06
10	10.00	5.50	10	100.00	50.50

Table 1: Outage Scale Factor, One-Way and Total Outage v. Fade Margin Reduction

Because of the significance of space diversity to this analysis, AT&T cautions that its use is not even remotely universal. Space diversity requires two receive antennas, each mounted at a different height on the receive site tower, as well as separate cabling, separate receivers, and the addition of a diversity combiner or selector. Space diversity therefore, in most cases,²⁵ doubles the equipment costs at the receive end, doubles tower space rental, and substantially increases installation costs. Ironically, space diversity is most common where the reliability concerns are highest and where operations are most sensitive to outages.

In such regards, RLAN proponents have also incorrectly assumed that all FS links employ adaptive modulation. With adaptive modulation deployed in an FS link, the link can downshift to a lower order modulation that is less susceptible to interference and continue communicating in the presence of interference, albeit at a slightly reduced data rate. Because, in AT&T's view, reliable adaptive modulation has only proven itself as a reliable technology in the past few years, and because most AT&T links operate at above 64QAM, AT&T estimates that the overwhelming majority (~85%) of its FS links are fixed modulation systems. When the noise becomes excessive, fixed modulation systems cannot switch to more robust modulations and transmit at lower speeds—they no longer operate at all.

As shown in Exhibit B, AT&T's engineering of fade margin for FS systems is very deliberate. And the service level required for a link is driven by network standards and downtime impacts. AT&T uses 6 GHz FS links, for example, to backhaul voice and data traffic from cell sites that are not served by fiber—outages on these types of links affect large numbers of subscribers, including potentially critical 9-1-1 calls. Moreover, as explained by APCO, the network downtime resulting from an even transient FS link outage can require resynchronization to bring the site back on-line, a process that can take 15 minutes.²⁶

²⁵ In some space diversity installations, a smaller receive antenna is utilized as the diversity antenna, a configuration that may cost slightly less, but will also result in slightly worse performance.

²⁶ Comments of APCO International, ET Docket No. 18-295, ET Docket No. 18-295 at 4 (filed Feb. 19, 2019).

WFA arguments in support of AFC-free VLP and LPI RLAN operation are deeply flawed.

Having failed to carry the day as a technical matter, WFA now resorts to arguments that, effectively, argue for prioritizing RLAN device manufacturers' economic interests over interference to FS systems, including vital public safety and utility links. None of these arguments is persuasive.

First, WFA argues that requiring universal AFC will delay market entry for Wi-Fi 6 devices, and that immediate market access is “urgently needed both for relieving Wi-Fi spectrum congestion and for the success of next-generation Wi-Fi technology (Wi-Fi 6).”²⁷ But as CTIA has pointedly observed, RLAN advocates have never explained why the relief WFA seeks is desperately needed and cannot be satisfied through other unlicensed bands. Moreover, and setting aside why these claims should shortcut needed regulatory protection for primary radio services, WFA's claims that 6 GHz spectrum is a gating factor for the introduction of Wi-Fi 6 devices is also belied by the fact that pre-standard Wi-Fi 6 devices have been on the market for some time using spectrum in the 5 GHz band.²⁸ And the Federated demonstration proves that AFC can be built within a reasonable timeframe after AFC requirements are addressed in a Report and Order.²⁹ As a final matter, one of the major disputes in this proceeding—and the resultant delay in resolution—is the RLAN advocates' insistence that universal AFC is not necessary without providing a sound technical basis for their claims. In short, there is no demonstrated compelling need to circumvent rational and considered decision-making by the Commission merely to facilitate the introduction of Wi-Fi 6 devices, given that those devices are already available.

Second, WFA claims that “AFC implementation entails additional cost and complexity.”³⁰ Although this is undoubtedly true, AT&T and other 6 GHz incumbents implement systems with significant complexity and great cost in order to co-exist with other FS users today. Indeed, wireless companies like AT&T not only pay substantial auction and secondary market costs to acquire the use of spectrum, but often also pay to clear the spectrum of incumbent users or fund

²⁷ WFA *Ex Parte* at 2 (stating that “there will be a substantial delay in the time required to complete the required technical design, testing, deployment, and regulatory certification of commercially viable AFC system(s), and it is only once these systems are approved by the Commission that companies can begin manufacturing and marketing compliant devices”).

²⁸ Westover, Brian, “Wi-Fi 6 Routers: What You Can Buy Now (and Soon),” Tom's Guide (Nov. 4, 2019) (noting availability, today, of Asus RT-AX88U, Asus ROG Rapture GT-AX11000, Netgear Nighthawk AX8, Netgear Nighthawk AX12, TP-Link Archer AX6000, all advertised as Wi-Fi 6 compatible); *available at*: <https://www.tomsguide.com/us/best-wifi-6-routers,review-6115.html> (last visited Nov. 6, 2019).

²⁹ HPE/Federated *Ex Parte* at 1 (stating “Federated Wireless has developed and demonstrated a fully functional AFC prototype that will accelerate the introduction of a variety of unlicensed services, while ensuring protection of existing services, in the 6 GHz band”).

³⁰ *Id.* at 3.

interference mitigation systems to hold existing users harmless. WFA must recognize that spectrum access entails regulatory compliance costs.

As a follow on to their cost argument, WFA complains that 6 GHz applications are so price-sensitive that the addition of needed interference prevention and mitigation requirements would “compromise their commercial viability in the extremely price-sensitive consumer-grade marketplace.”³¹ This assertion, however, directly undercuts their argument that consumer need for these devices is so high that normal regulatory requirements to safeguard incumbents must be overridden. Either the spectrum is critically needed for consumer uses—in which case AFC costs spread across hundreds of millions of devices seems a small incremental price tag—or consumers’ need for this spectrum is so marginal that they place little value on it.

Finally, WFA argues that “Wi-Fi’s success, in large part, depends on global market access . . . [and] [r]equiring U.S. manufacturers to conform to a patchwork of national regulations would be detrimental to U.S. consumers, economic interests, and technological leadership goals.”³² As a company whose wireless operations rely on globally-standardized base station, network and end user equipment, AT&T is well aware of the issues that can arise with a “patchwork of national regulations.” That said, even equipment that is nominally “globally harmonized” must address local variations including, among other things, frequency bands for operation. Like other localized spectrum access requirements, AFC can be implemented within Wi-Fi devices and switched on or off as the local market requires. Notably, WFA’s dire predictions regarding standards have not prevented its manufacturer members from, time and time again, releasing pre-standards, localized devices that are later updated through firmware to become current.

Should any questions arise concerning this *ex parte*, please do not hesitate to contact me at (202) 457-2055.

Sincerely,

/s/ Michael P. Goggin

Michael P. Goggin

³¹ *Id.*

³² *Id.*

Radio Local Area Network (RLAN) to Fixed Service (FS) Microwave Interference in the 6 GHz Band

Analysis of Select Real World Scenarios

Context

- RLAN advocates seek to eliminate automatic frequency coordination (AFC) requirements for “low power” indoor and “very low power” devices
 - These devices are not “low”/“very low” power—the “low power” RLAN devices operate with the **same** maximum power limit (EIRP) as handsets in the **licensed** AWS service
 - RLAN advocates have completely failed to make a technical non-interference case—Boeing admits “**interference events inevitably will occur for some fixed links**” (Boeing Nov. 1 *ex parte*)
 - RLAN advocates are now arguing that even though interference is inevitable, the “statistical probability is low (although how low is in dispute),” *id.*, and FS operations can mitigate any interference that results
 - Primary licensees cannot be required to accept interference from unlicensed users and should not bear the cost of implementing costly upgrades to remediate interference
 - The probability of interference is not low—AT&T’s examples herein are not “worst case” and were identified by reviewing only a couple dozen out of thousands of FS links in its portfolio
 - The changes in uptime reliability for these links is many times larger than, for example, in MVDDS, a secondary service with superior rights than unlicensed RLANs, where the FCC found that a percentage uptime availability change for DBS (a consumer service) of 10% constituted “harmful interference”

Objectives

- Analyses to date have relied upon unrealistic parameters
 - Statistical analyses discount potential impacts to situations outside the mean, even though real world scenarios exist in those categories
 - Unrealistic simplification of Building Entry Loss—attenuation of RLAN interference to FS resulting from indoor operation
- AT&T has modeled the impact of RLAN operation to actual FS facilities operated by AT&T
 - RLAN operating assumptions are realistic—actual buildings selected for modeling are locations where RLAN use would be anticipated
 - AT&T's modeling utilizes conservative assumptions, but also factors in a more rigorous analysis of potential Building Entry Loss effects
- AT&T's real world deployment scenarios demonstrate that RLAN interference to FS links is a significant problem and that RLANs require Automatic Frequency Control (AFC) to avoid harmful interference to incumbent FS systems

Analysis Overview

- FS data reflects properties of links licensed and operating in AT&T's communications network
- The Interference Power to the victim FS receiver is calculated as:

$$I = P_{TX} - L_P + G_{RX} - L_D - L_{WG} - Adj_{BW\&Adj}$$

- The RLAN EIRP limit from an outdoor RLAN is then defined by the following equation with the interference power I set to its maximum permissible level

$$P_{TX} = I + L_P - G_{RX} + L_D + L_{WG} + Adj_{BW\&Adj}$$

I : Received Interference power in dBm

P_{TX} : RLAN EIRP in direction of the victim in dBm

L_P : Propagation Loss in dB

G_{RX} : Victim Antenna Gain in dBi

L_D : Victim Antenna Discrimination in dB

L_{WG} : Any Waveguide Loss and polarization loss in dB

$Adj_{BW\&Adj}$: Adjustments for bandwidth correction accounting for adjacent channel interference in dB

- Sensitivity analysis on building loss for traditional and thermal efficient windows is shown based on 25%, 50% and 75 % probability distribution.

Analysis Overview (Cont'd)

- The theoretical minimum noise floor of a 30 MHz channel is given by

$$-173.8 \text{ dBm/Hz} + 10 \log_{10}(30 \times 10^6) \text{ Hz} = -99.0 \text{ dBm}$$

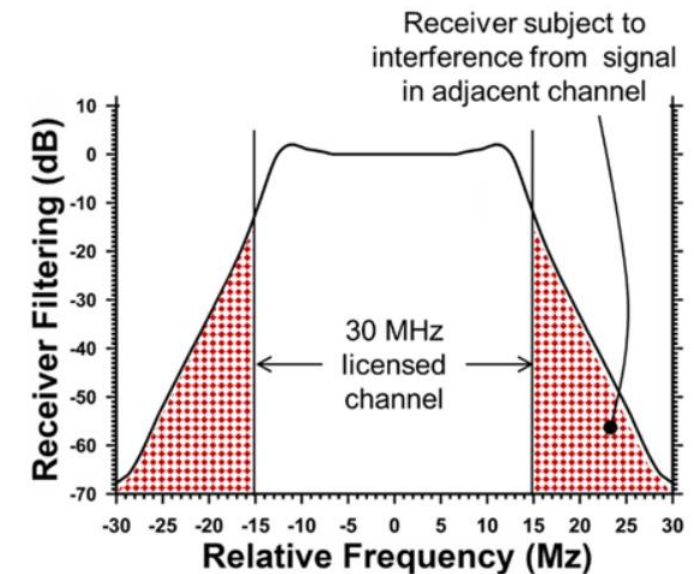
- Assuming a receiver noise figure of 3.0 dB and an I/N requirement of -12.0 dB results in a maximum permissible interference level of:

$$-99.0 \text{ dBm} + 3.0 \text{ dB} - 12.0 \text{ dB} = -108.0 \text{ dBm}$$

- For I/N requirements of -6 dB and -9 dB, the maximum permissible interference levels would be, respectively, -102 dBm and -105 dBm
- AT&T has argued the appropriate I/N should be -12 dB, but has provided other I/N values for informational purposes

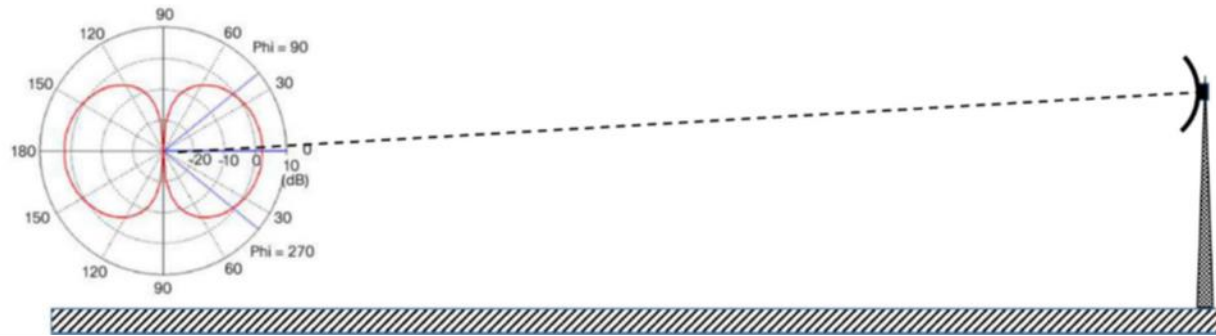
Analysis Assumptions

- Line of sight, free space propagation
 - Can be validated from photographs in scenarios analyzed
- Conservative 3 dB polarization mismatch adjustment
 - CTIA has argued—correctly—that “polarization discrimination is predictable **only for systems that can guarantee antenna placement and orientation**” (CTIA *Ex Parte*, filed Oct. 22, 2019)
 - Although an RLAN antenna is adjustable and its orientation cannot be guaranteed, AT&T has nonetheless applied a 3 dB polarization mismatch adjustment to be conservative
- Conservative 3 dB bandwidth mismatch adjustment
 - Considers impact of RLAN use of 80 MHz channels while FS systems under analysis have 30 MHz channelization
 - While RLAN proponents have used a larger adjustment factor, they are ignoring that FS receivers will still be affected by RLAN emissions from “adjacent” FS channels
 - In other words, inability to filter reception of out-of-band signals gives FS systems a wider “virtual” bandwidth
 - AT&T believes the appropriate adjustment is thus only 3 dB



Analysis Assumptions (Cont'd)

- The analysis factors in RLAN antenna pattern mismatch, *i.e.*, reduces the RLAN antenna gain when the interference path is above or below the horizontal (azimuth) plane directly in front of the RLAN antenna
 - Because most RLAN access points will have near-zero antenna attenuation in the direction of the FS, the reduction in gain is generally not significant



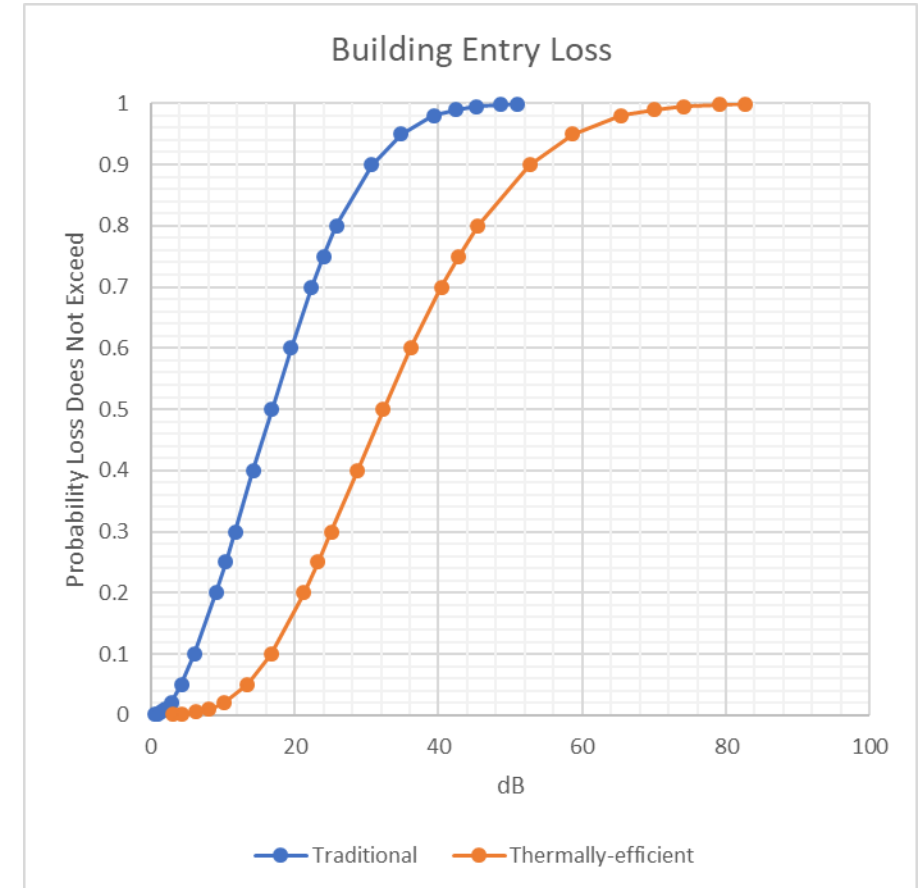
- The analysis considers FS receiver feeder loss, *i.e.*, adjusts for the loss between the FS receive antenna and the input to the FS receiver
 - This information is not in the ULS database and is therefore an estimate
 - Not all sites have feeder loss in the link budget

Modeling Building Entry Loss

- Prior RLAN analyses oversimplify Building Entry Loss (BEL), which must be modeled as a distribution function rather than a simple average
 - As CTIA notes “ITU-R Rec. P.2109-0 on BEL requires sharing studies to use the **full distribution**, not a single level of loss” (CTIA *Ex Parte*, filed Oct. 22, 2019)
 - Building Entry Loss is dependent upon a variety of factors that include, among other things, RLAN location in the building relative to materials with differing attenuation, the attenuation range of the building materials, and the transmission angle in relation to the windows
- ITU-R P.2109 provides a distribution of Building Entry Loss as a function of frequency and elevation angle for two classes of building construction
 - The building construction classes are “thermally-efficient” and “traditional”
 - Thermally-efficient buildings typically use metalized glass windows and metal foil backed insulation which provide significantly different radio frequency shielding
 - AT&T has modeled both types of buildings even though in some scenarios it is clear from visual inspection that the building would not have thermally-efficient construction

Modeling Building Entry Loss (Cont'd)

- The chart shows BEL for 6.5 GHz and zero elevation
 - Different curves for traditional v. thermally efficient construction
 - Curves represent probability that loss **does not exceed** the attenuation shown
 - In other words, there is a 75% probability that BEL will not be greater than 24 dB for traditional construction—a 25% probability attenuation will be at least 24 dB
 - The higher probability the analysis reflects, the lower the attenuation that can be assumed—being 100% sure requires assuming 0 dB attenuation
- AT&T's analysis calculates elevation for the RLAN signals to the FS victim receiver and adjusts the BEL probabilities accordingly



Modeling Building Entry Loss (Cont'd)

- Table 1 below shows the impact of elevation on the BEL, showing the impact at 25%, 50% and 75% probabilities for dB values *not* exceeded

Elevation [deg]	Traditional Construction			Thermally-efficient		
	25%	50%	75%	25%	50%	75%
0	10.4	16.8	24.0	23.2	32.3	42.8
5	11.1	17.8	25.0	23.8	33.2	43.8
10	11.9	18.7	26.1	24.4	34.1	44.8
15	12.8	19.7	27.1	25.1	35.0	45.9
20	13.7	20.7	28.2	25.8	36.0	46.9

- There is a 25% chance that the BEL is less than 10.4 dB, and consequently a 75% chance it is greater than 10.4 dB
- There is a 75% chance the BEL is less than 24.0 dB, and consequently only a 25% chance it is greater than 24.0 dB
- ITU-R Rec. P2019 conservatively assumes transmitters are randomly distributed
 - In situations where the user is motivated to provide coverage to outside areas next to the building from inside, the deployment of the transmitter will not be random
 - For example, if a residential user wishes to cover an outside deck, pool, disconnected garage or shed from inside they will likely select an indoor transmitter location that provides as much signal outdoors as possible
 - In these situations, the BEL is likely to be significantly less than the predicted median value

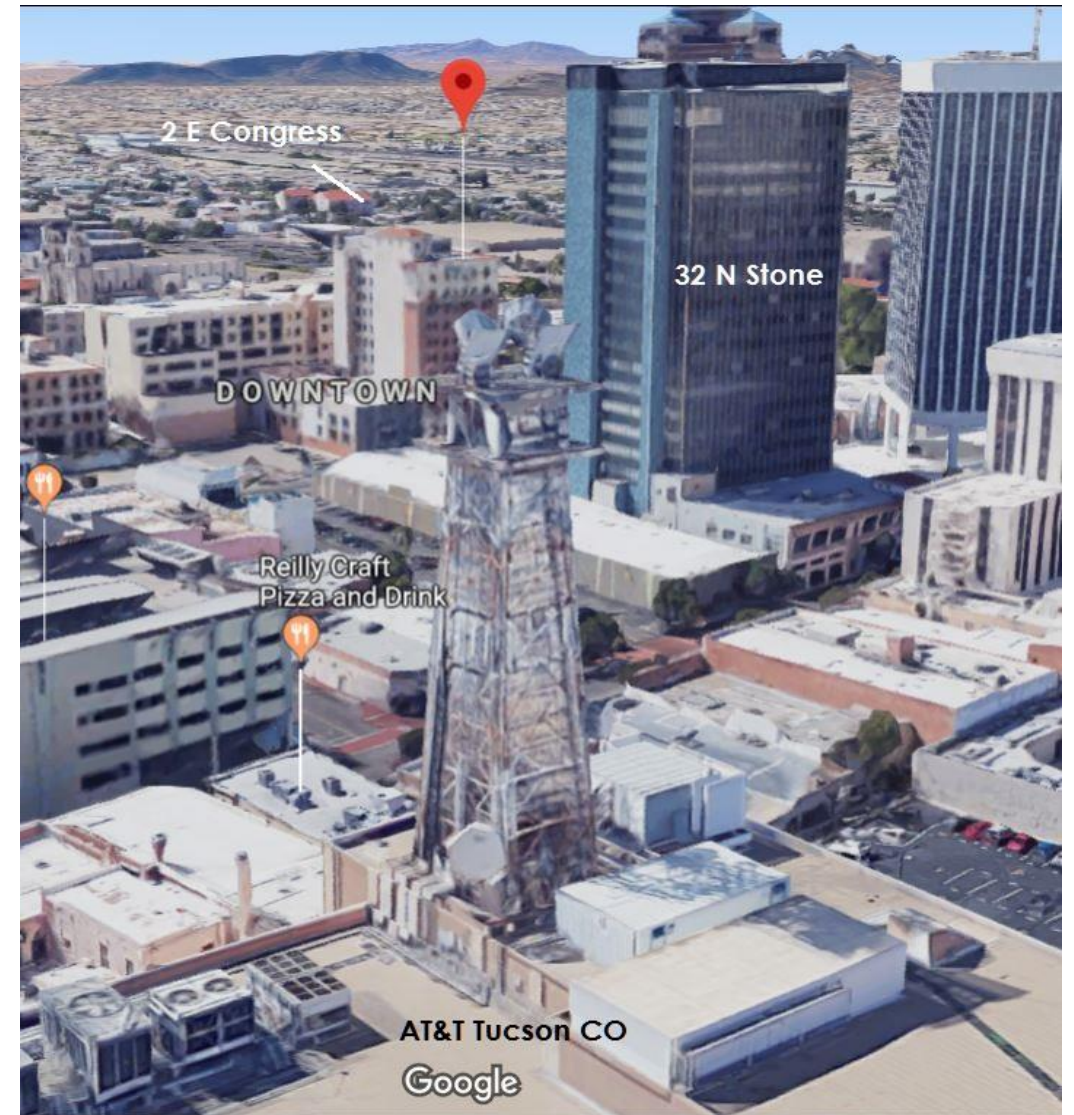
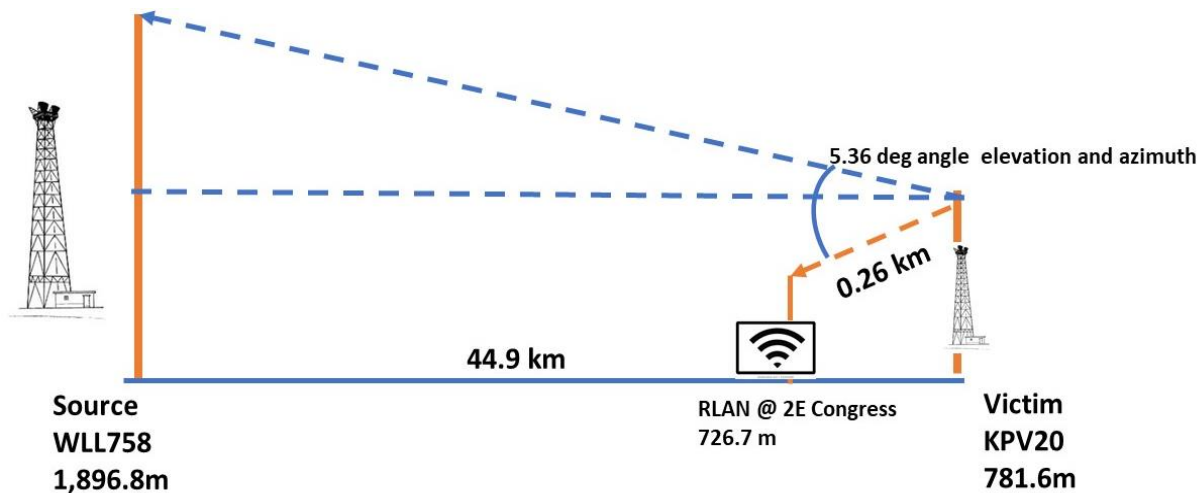
RLAN to FS Interference Examples

- Example 1A, 1B: KPV20 Tucson, AZ
 - Urban area, high buildings in FS link path; close distances but high discrimination angle
 - Example 1A has more detail—other examples use similar calculations but are not shown
- Example 2: WQPJ679 Batavia, NY
 - Longer distance between RLAN and FS, but RLAN closer to main beam
- Example 3: WQXC429 Sun Tan Valley, AZ
 - Longer distance, but RLAN on naturally higher ground and closer to main beam
- Example 4: WLU230 Lynnwood, WA
 - Short distance, high RLAN antenna discrimination factor
- Example 5: WQWA497 Gehring, NE
 - Very short distance, very high RLAN antenna discrimination factor

All examples show very high potential—based on BEL probabilities—of causing interference to FS incumbents

Example 1A: WLL758 > KPV20, RLAN at 2 E. Congress

- FS link to AT&T's CO in Tucson, AZ
 - Low Path loss – 0.26 km between RLAN and victim FS receiver
 - High FS antenna discrimination factor (36 dB) between RLAN and victim FS receiver
- RLAN at 36m AGL with transmit power of 30 dBm



Example 1A: WLL758 > KPV20, RLAN at 2 E. Congress

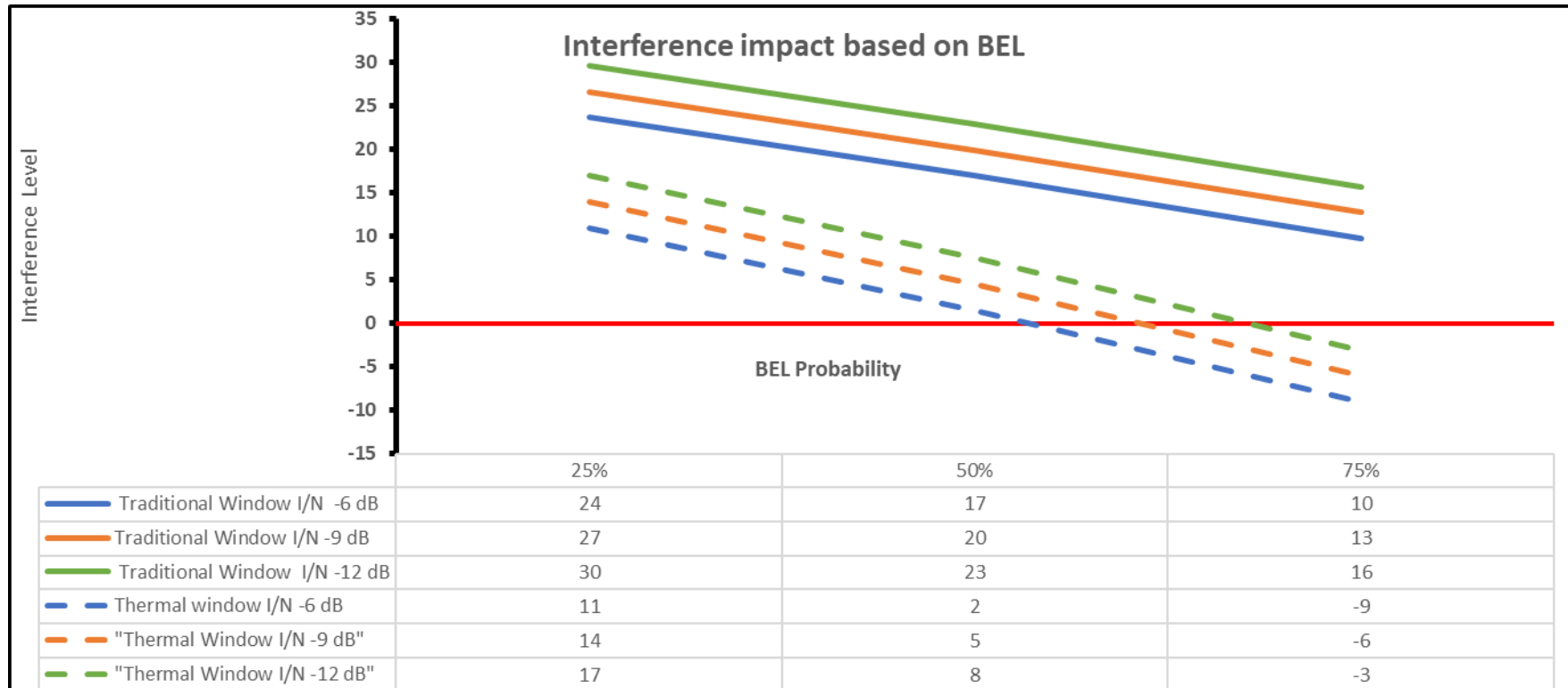
		Victim KPV20	Source WLL758	2 E Congress
Height AGL	m	54.9	19.8	36
Height ASL	m	781.6	1896.8	762.7
Lat		32.2	31.9	32.22
Lon		-111.0	-111.2	-110.97
$\theta_{\text{Elevation}}^*$	deg		1.27	-4.09
θ_{Azimuth}	deg		211.14	211.13

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{\text{Elevation}}^*$	deg	5.36		
θ_{Azimuth}	deg	0.00		
$\Delta\theta$	deg	5.36		
Dist. Source > Victim	km	0.00		
Dist. RLAN > Victim	m	265.22		
Path Loss	dB	96.45		
Antenna Gain	dBi	43.20		
Antenna Discrimination	dB	36.00		
Other losses incl Pol	dB	5.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-4.75	-7.75	-10.75

Example 1A: RLAN Impact on KPV20

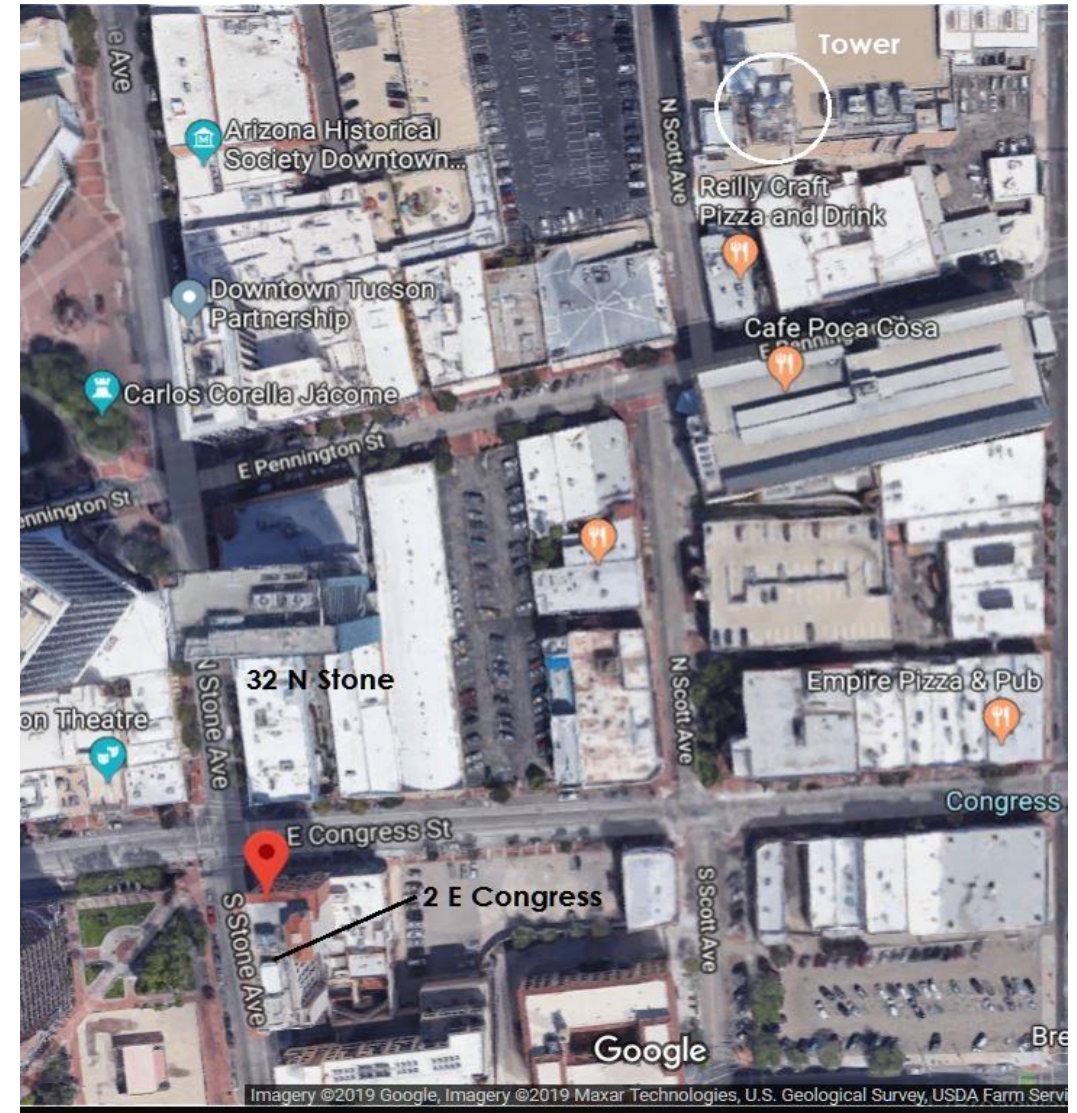
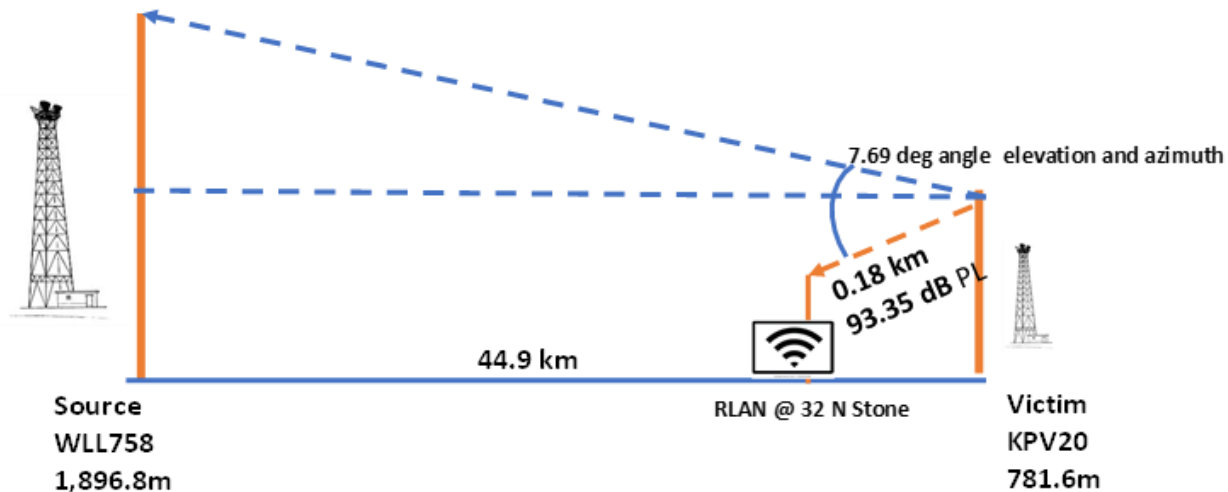
- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL “not to exceed” values



- RLAN will almost certainly exceed interference threshold in both cases

Example 1B: WLL758 > KPV20, RLAN at 32 N. Stone

- Same FS link to AT&T's CO in Tucson, AZ used in Example 1A
 - Low Path loss – 0.19 km between RLAN and victim FS receiver
 - High FS antenna discrimination factor (38 dB) between RLAN and victim FS receiver
- RLAN at 59m AGL with transmit power of 30 dBm



Example 1A: WLL758 > KPV20, RLAN at 32 N. Stone

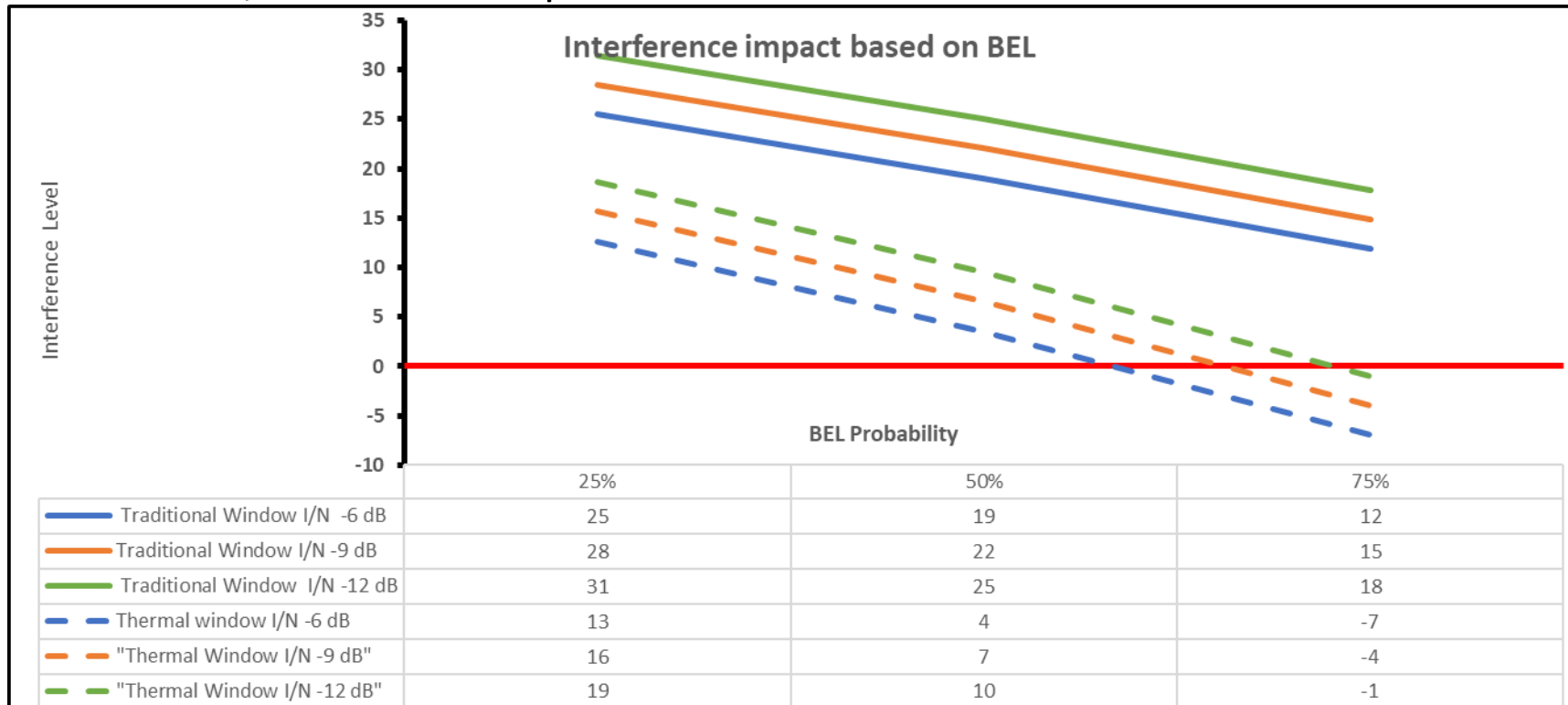
	Units	Victim KPV20	Source WLL758	32 N Stone
Height AGL	m	54.9	19.8	59
Height ASL	m	781.6	1896.8	785.7
Lat		32.2	31.9	32.22
Lon		-111.0	-111.2	-110.97
$\theta_{\text{Elevation}}^*$	deg		1.27	1.27
θ_{Azimuth}	deg		211.14	218.83

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{\text{Elevation}}^*$	deg	0.00		
θ_{Azimuth}	deg	-7.69		
$\Delta\theta$	deg	7.69		
Dist. Source > Victim	km	44.92		
Dist. RLAN > Victim	m	185.10		
Path Loss	dB	93.35		
Antenna Gain	dBi	43.20		
Antenna Discrimination	dB	38.00		
Other losses incl Pol	dB	5.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-5.85	-8.85	-11.85

Example 1B: RLAN Impact on KPV20

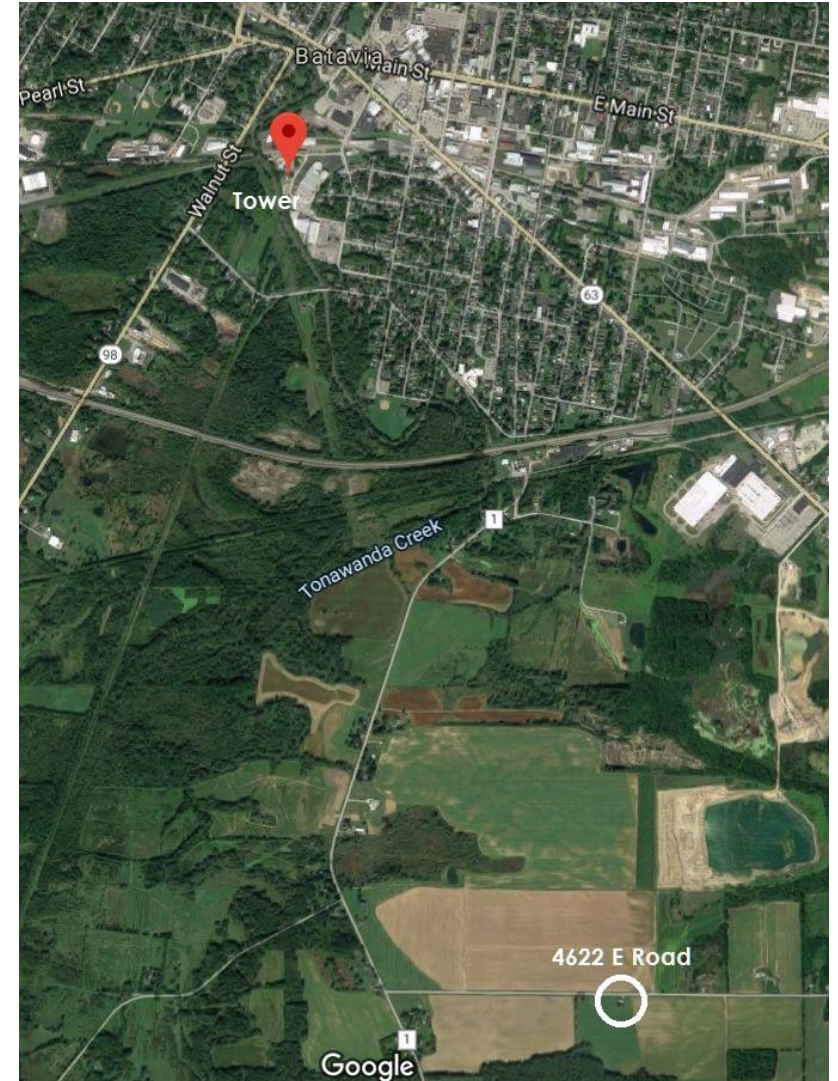
- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL “not to exceed” values



- RLAN will almost certainly exceed interference threshold in both cases

Example 2: WQPJ677 > WQPJ679, RLAN at 4622 E. Rd

- FS link in Batavia, NY
 - 3.5 km between RLAN and victim FS receiver
 - Low FS antenna discrimination factor (1.5 dB) between RLAN and victim FS receiver
- RLAN at 1.5m AGL with transmit power of 30 dBm



Example 2: WQPJ677 > WQPJ679, RLAN at 4622 E. Rd

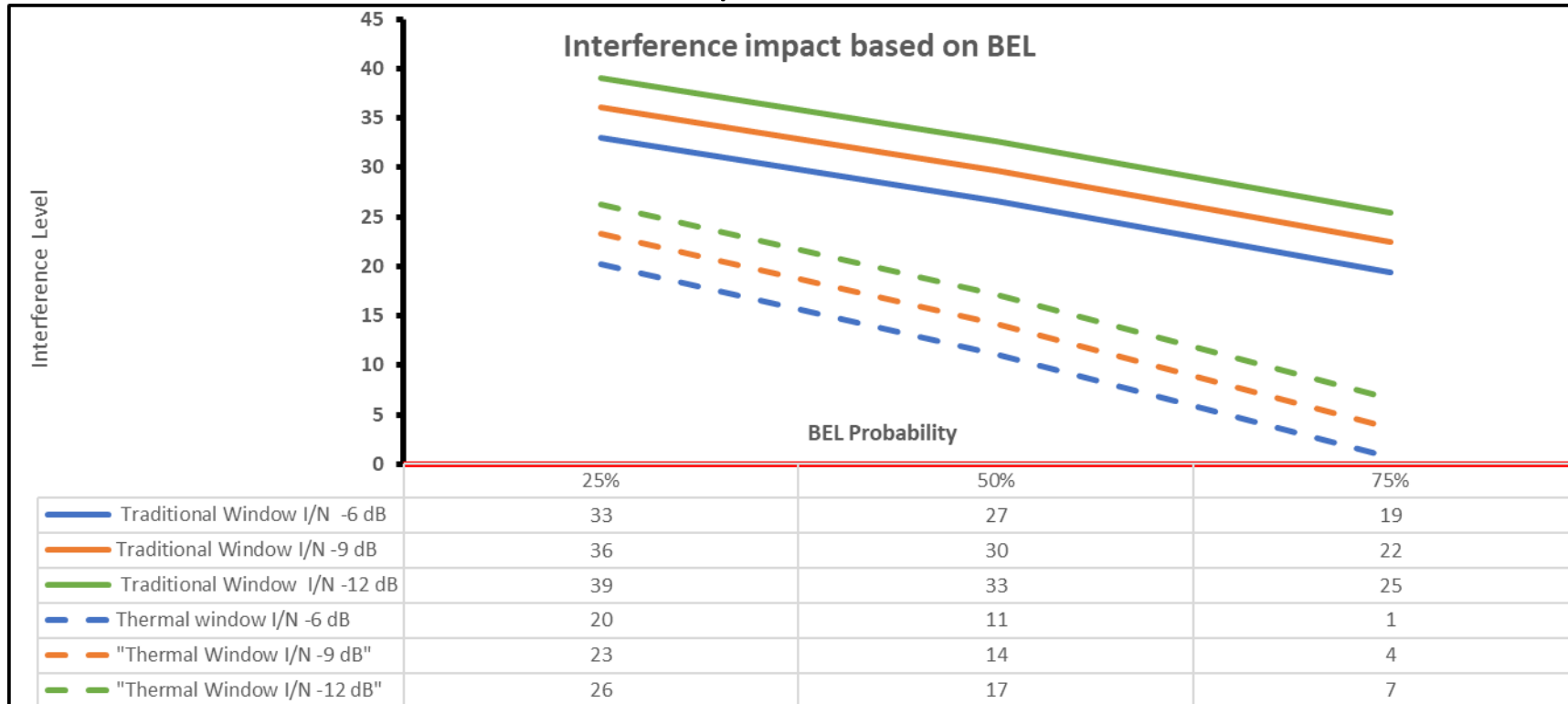
	Units	Victim WQPJ679	Source WQPJ677	4622 E Rd
Height AGL	m	27.4	42.7	1.5
Height ASL	m	299.3	406.9	276.5
Lat		43.0	42.9	42.96
Lon		-78.2	-78.1	-78.17
$\theta_{\text{Elevation}}^*$	deg		0.55	-0.38
θ_{Azimuth}	deg		157.71	157.81

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{\text{Elevation}}^*$	deg	0.93		
θ_{Azimuth}	deg	-0.10		
$\Delta\theta$	deg	0.94		
Dist. Source > Victim	km	10.53		
Dist. RLAN > Victim	m	3528.14		
Path Loss	dB	118.96		
Antenna Gain	dBi	37.90		
Antenna Discrimination	dB	1.50		
Other losses incl Pol	dB	3.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-13.44	-16.44	-19.44

Example 2: WQPJ677 > WQPJ679, RLAN at 4622 E. Rd

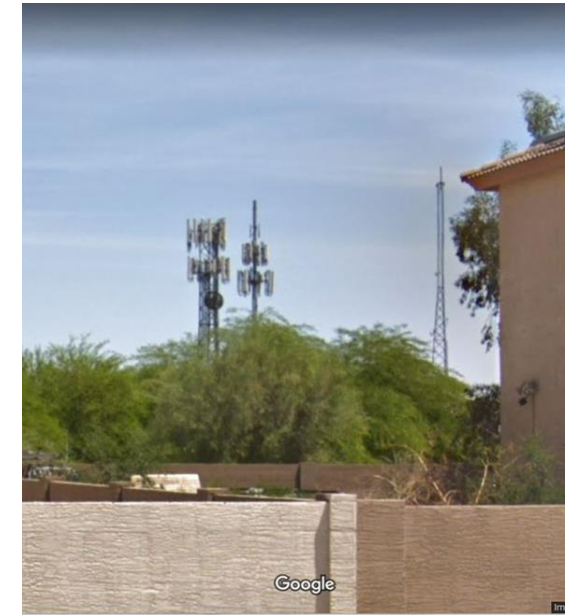
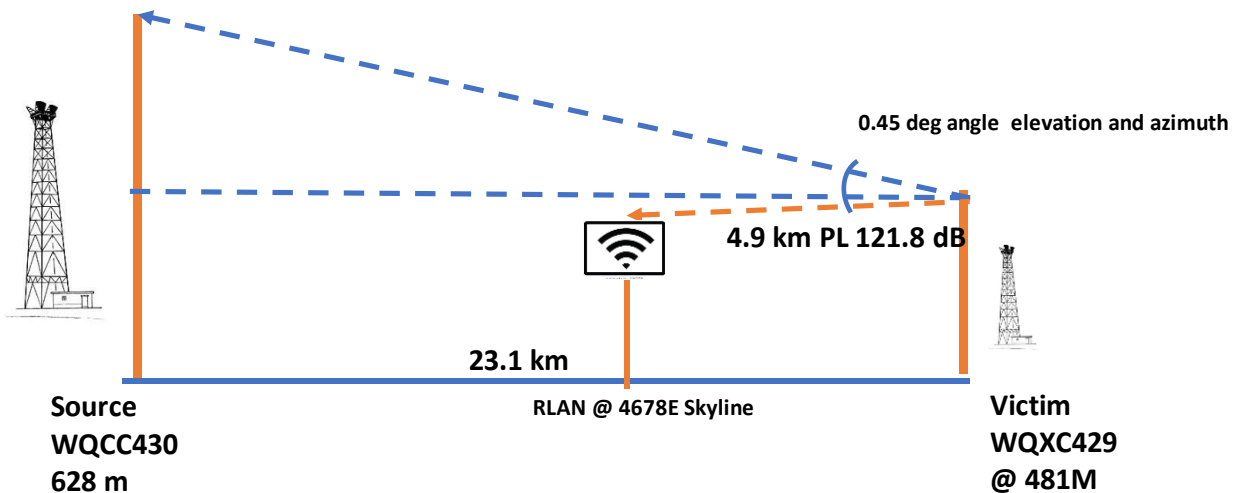
- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL “not to exceed” values



- RLAN exceeds interference threshold in both cases

Example 3: WQXC430 > WQXC429, RLAN at 4678 E. Skyline

- FS link in Sun Tan Valley, AZ
 - Almost 5 km between RLAN and victim FS receiver
 - Low FS antenna discrimination factor (0.9 dB) between RLAN and victim FS receiver
- RLAN at 2m AGL with transmit power of 30 dBm
 - GL is 21.3m at victim, but 472m at RLAN



Example 3: WQXC430 > WQXC429, RLAN at 4678 E. Skyline

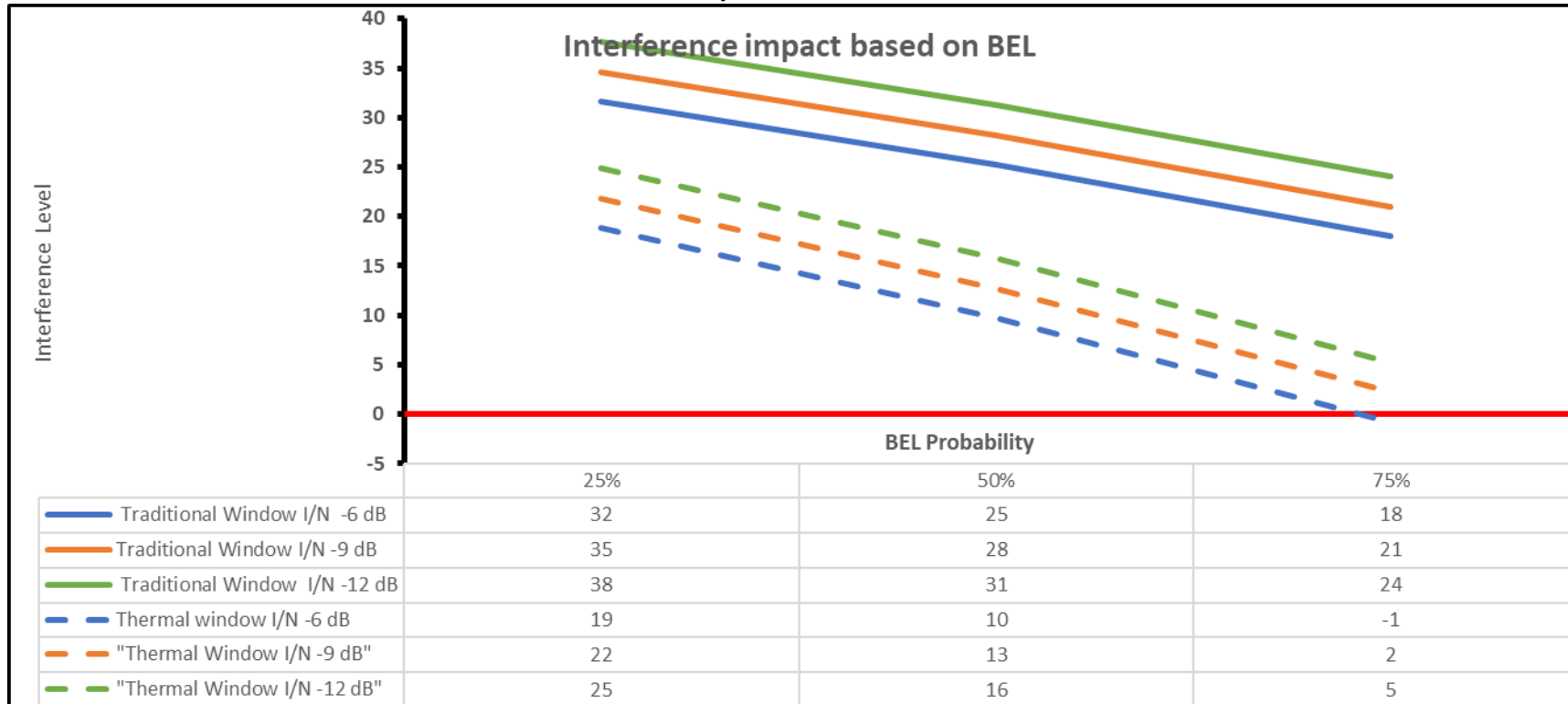
	Units	Victim WQXC429	Source WQXC430	4678 E Skyline
Height AGL	m	21.3	51.8	2
Height ASL	m	481.6	628.5	472
Lat		33.2	33.3	33.19
Lon		-111.6	-111.3	-111.52
$\theta_{\text{Elevation}}^*$	deg		0.29	-0.13
θ_{Azimuth}	deg		65.04	64.85

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{\text{Elevation}}^*$	deg	0.41		
θ_{Azimuth}	deg	0.19		
$\Delta\theta$	deg	0.46		
Dist. Source > Victim	km	23.17		
Dist. RLAN > Victim	m	4938.09		
Path Loss	dB	121.88		
Antenna Gain	dBi	38.80		
Antenna Discrimination	dB	0.90		
Other losses incl Pol	dB	3.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-12.02	-15.02	-18.02

Example 3: WQXC430 > WQXC429, RLAN at 4678 E. Skyline

- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL “not to exceed” values



- RLAN will exceed interference threshold in both cases

Example 4: WPTX494 > WLU230, RLAN at Vet Clinic

- FS link in Lynnwood, WA
 - Low Path loss – 0.17 km between RLAN and victim FS receiver
 - High FS antenna discrimination factor (38 dB) between RLAN and victim FS receiver
- RLAN at 2m AGL with transmit power of 30 dBm



Example 4: WPTX494 > WLU230, RLAN at Vet Clinic

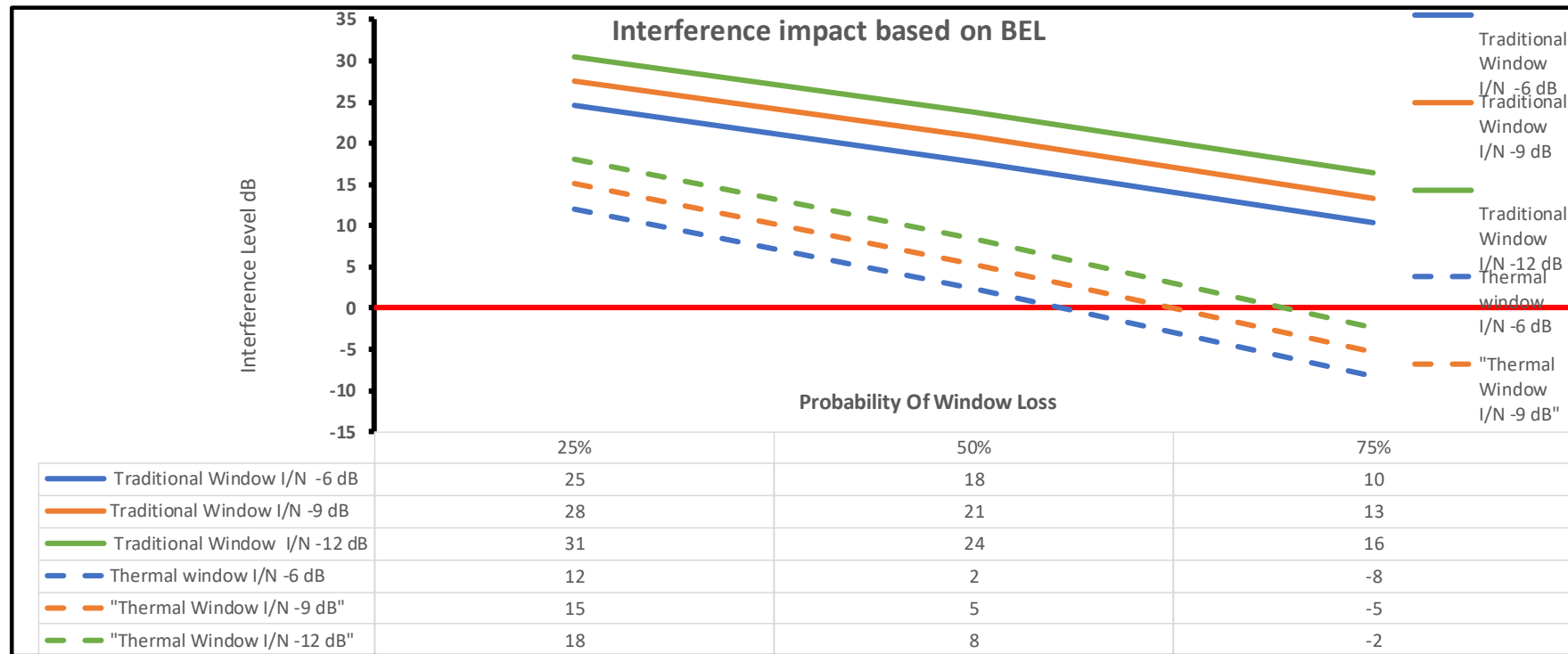
	Units	Victim WLU230	Source WPTX494	Vet Clinic
Height AGL	m	44.5	43.3	2
Height ASL	m	236.2	202.1	193.7
Lat		47.9	47.9	47.86
Lon		-122.3	-122.7	-122.29
$\theta_{\text{Elevation}}^*$	deg		-0.17	-14.10
θ_{Azimuth}	deg		273.95	275.58

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{\text{Elevation}}^*$	deg	13.93		
θ_{Azimuth}	deg	-1.63		
$\Delta\theta$	deg	14.02		
Dist. Source > Victim	km	0.00		
Dist. RLAN > Victim	m	174.43		
Path Loss	dB	92.84		
Antenna Gain	dBi	41.30		
Antenna Discrimination	dB	38.00		
Other losses incl Pol	dB	3.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-6.46	-9.46	-12.46

Example 4: WPTX494 > WLU230, RLAN at Vet Clinic

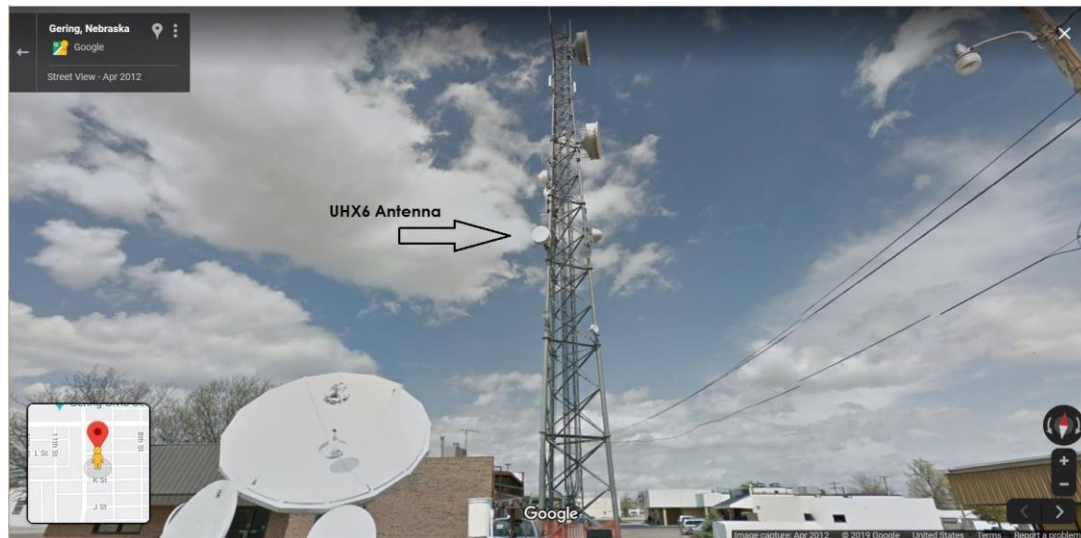
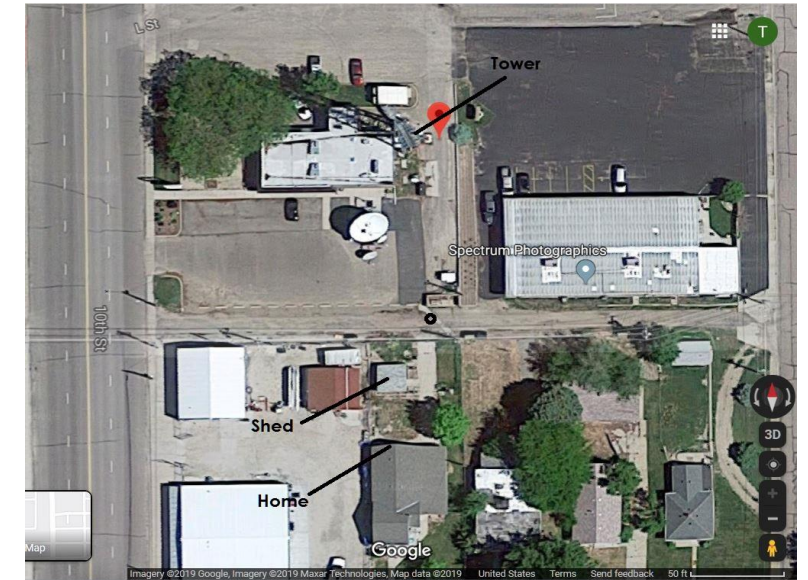
- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL “not to exceed” values



- RLAN will almost certainly exceed interference threshold in both cases

Example 5: WWA496 > WQWA497, RLAN at K St Home

- FS link to AT&T's CO in Gering, NE
 - Low Path loss – only 50m between RLAN and victim FS receiver
 - High FS antenna discrimination factor (38.8 dB) between RLAN and victim FS receiver
- RLAN at 1.5m AGL with transmit power of 30 dBm



Example 5: WWA496 > WQWA497, RLAN at K St Home

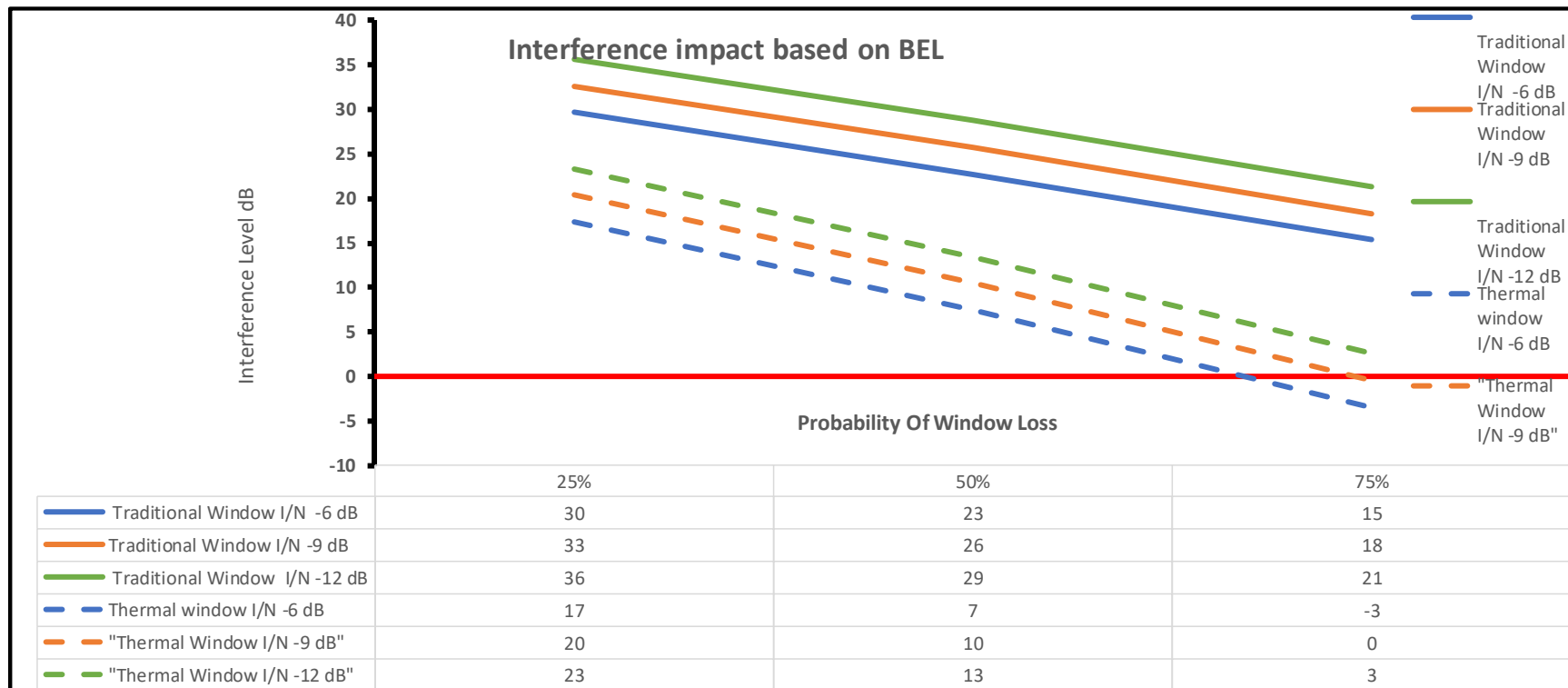
	Units	Victim WQWA497	Source WQWA496	K St Home
Height AGL	m	15.2	19.8	1.5
Height ASL	m	1207.6	1464.6	1193.9
Lat		41.8	41.7	41.82
Lon		-103.7	-103.7	-103.66
$\theta_{\text{Elevation}}^*$	deg		1.07	-15.23
θ_{Azimuth}	deg		188.77	179.14

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{\text{Elevation}}^*$	deg	16.30		
θ_{Azimuth}	deg	9.63		
$\Delta\theta$	deg	18.68		
Dist. Source > Victim	km	0.00		
Dist. RLAN > Victim	m	52.15		
Path Loss	dB	82.35		
Antenna Gain	dBi	38.80		
Antenna Discrimination	dB	40.00		
Other losses incl Pol	dB	3.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-12.45	-15.45	-18.45

Example 5: WWWA496 > WQWA497, RLAN at K St Home

- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL “not to exceed” values



- RLAN will almost certainly exceed interference threshold in both cases

Microwave Fixed Service Fade Margin Calculation

November 12, 2019

Weather Related Fading

Fading outages on a microwave radio can come from flat fading, dispersive fading and rain fading. Both flat fading and dispersive fading are quite frequency dependent. Consequently, for microwave radio communication systems using Frequency Division Duplex (FDD), like most systems in the 6 GHz bands, where a different carrier frequency is used for each direction of communication, outages from these fading mechanisms are uncorrelated in each direction. Therefore, the TIA-10 strategy to compute total fading outage on FDD microwave paths involves computing the expected one-way flat fading outage time, one-way dispersive fading outage time and rain fading outage time. The total outage on the two-way FDD path is then the sum of rain outage time plus two times the one-way dispersive and flat fading outage times. See ANSI TIA-10 section 10.5.

For longer paths operating at frequencies below 10 GHz, rain fading is usually negligible compared to flat and dispersive fading. Outage from dispersive fading can be reduced by using adaptive equalizers in the radio receiver. The equalizers in modern radios are usually capable of reducing outage from dispersive fading to a small fraction of the flat fading outage. Outage from flat fading depends, among other factors, on the flat fade margin of the microwave radio path. Received interference can reduce the flat fade margin and increase outage times.

Fade Margin and Interference

To properly decode a received signal utilizing a particular modulation, a minimum Signal to Interference plus Noise Ratio (SINR) is required. The flat fade margin on a microwave radio path is the difference, in dB, between the actual fair weather SINR and the required minimum SINR. The fair weather SINR, and consequently the fade margin, will be reduced if the receiver is subjected to interference power. If n is the receiver noise power and i is its interference power, both in mW, the noise plus interference power in dBm is:

$$10\log_{10}(n + i) = 10\log_{10}[n(1 + i/n)] = 10\log_{10}(n) + 10\log_{10}(1 + i/n)$$

Therefore, the increase in noise plus interference power expressed in dB, relative to just the noise power is given by the term $10\log_{10}(1 + i/n)$. This is the amount, in dB, that the radio fade margin is decreased by interference. Expressing i/n in dB, so that $I/N \equiv 10\log_{10}(i/n)$, the dB reduction in fade margin due to interference is given by:

$$\Delta FM = 10\log_{10}(1 + 10^{0.1 \cdot I/N})$$

This fade margin reduction, ΔFM , is tabulated below for select I/N values from -10 dB to +10 dB.

I/N [dB]	-10	-8	-6	-5	-4	-3	-2	-1	+0	+1	+2	+3	+4	+5	+6	+8	+10
ΔFM [dB]	0.4	0.6	1.0	1.2	1.5	1.8	2.1	2.5	3.0	3.5	4.1	4.8	5.5	6.2	7.0	8.6	10.4

Table 1 - Fade Margin Reduction for Various I/N Values

One-way Flat Fading

According to TIA-10, the expected number of seconds of one-way outage due to flat fading on a point-to-point microwave path without diversity is proportional to $10^{-FFM/10}$ where FFM is the flat fade margin in dB. For a microwave path with space diversity the outage is proportional to $10^{-2FFM/10}$. These relationships can be seen by examining the equations in TIA-10 section 10.6 as discussed next. These formulas are valid for predicting percentage outages less than about 0.2% (~17.5 hr/yr or 63,000 sec/yr).

The expected number of seconds of outage per year on a point-to-point microwave path, in one direction, due to flat multipath fading, T_F , is given by the following equation in TIA-10 section 10.6.

$$T_F = \frac{T_S}{I_F} R \times 10^{-FFM/10} = \frac{T_S}{I_F} c \left(\frac{50}{w} \right)^{1.3} \frac{f}{4} D^3 \times 10^{-5-FFM/10}$$

Since the fade occurrence rate is given by

$$R = c \left(\frac{50}{w} \right)^{1.3} \frac{f}{4} D^3 \times 10^{-5}$$

Where

T_S	Seconds in annual fading season
I_F	Diversity improvement factor
R	Fade occurrence rate
c	Location based C factor
w	Terrain roughness in ft
f	Frequency in GHz
D	Path length in miles

The number of seconds in an annual fading season is given by:

$$T_S = 8 \times 10^6 \frac{t}{50}$$

Where t is the average annual Fahrenheit temperature of the area where the path is located under the constraint that $35 < t < 75$.

The terrain roughness is a measure of the standard deviation of terrain heights along the propagation path under the constraint that $20 \leq w \leq 140$.

For a microwave radio path that does not employ any type of diversity $I_F = 1$.

Consequently, for a point-to-point microwave radio system without diversity, the ratio of one-way flat fading outage when it experiences interference to the same path without interference is:

$$\rho_{ND} \equiv \frac{10^{-(FFM-\Delta FM)/10}}{10^{-FFM/10}} = 10^{\Delta FM/10}$$

Where ΔFM is the fade margin reduction in dB caused by the interference.

For a path using space diversity

$$I_F = 7 \times 10^{-5} \eta s^2 (f/D) 10^{(G_D - G_P)/10} \times 10^{FFM/10}$$

Provided that $1 \leq I_F \leq 200$ and where:

η	Switching hysteresis efficiency $0 < \eta \leq 1$
s	Antenna spacing in ft
G_P	Gain of Primary RX antenna in dBi
G_D	Gain of Diversity RX antenna in dBi

Hence for the space diversity case

$$\begin{aligned} T_F &= \frac{T_S}{I_F} R \times 10^{-FFM/10} = \frac{T_S R}{7 \times 10^{-5} \eta s^2 (f/D) 10^{(G_D - G_P)/10} \times 10^{FFM/10}} \times 10^{-FFM/10} \\ &= T_S \frac{c(50/w)^{1.3} D^4}{28 \eta s^2 10^{(G_D - G_P)/10}} \times 10^{-2FFM/10} \end{aligned}$$

Assuming the same interference power is received by both the primary and diversity receive antennas, there is again a simple relationship for the ratio of one-way flat fading outage with interference to that without interference. This ratio is given by:

$$\rho_{SD} \equiv \frac{10^{-2(FFM-\Delta FM)/10}}{10^{-2FFM/10}} = 10^{2\Delta FM/10}$$

Where ΔFM is the reduction of fade margin on the primary and diversity receivers due to interference.

Total Fading Outage

Typically, 6 GHz microwave paths are engineered in a symmetric manner, such that the one-way flat fading outage, without interference, is the same for each direction of transmission. It is also often the case that the outage on a 6 GHz path is dominated by flat fading, compared to dispersive and rain fading. If both these conditions hold, it is possible to estimate the effect of interference to the total outage on the path. For this situation—in the absence of other interference—nearly half the outage is due to flat fading in one direction of transmission and half the outage due to flat fading in the other direction. Assuming only interference into the

receiver at one end of the path, the flat fading outage in that direction will be increased by the ρ scale factor. This approximation estimates the ratio of the total outage with this interference to the total outage without interference as $(1 + \rho)/2$.

The table below lists the one-way and estimated total outage scale factors for various reductions of fade margin in one direction of transmission due to interference. As can be seen in the table, just a few dB reduction in fade margin has a significant effect on outage time. For a mere 3 dB reduction in fade margin ($I/N = 0$ dB) on one end of a path without diversity, the expected total outage time increases by about 50%. For a path with space diversity the same 3 dB loss of fade margin at one end increases the expected total outage time by almost 150%.

No Diversity			Space Diversity		
ΔFM [dB]	One-way	Total	ΔFM [dB]	One-way	Total
1	1.26	1.13	1	1.58	1.29
2	1.58	1.29	2	2.51	1.76
3	2.00	1.50	3	3.98	2.49
5	3.16	2.08	5	10.00	5.50
7	5.01	3.01	7	25.12	13.06
10	10.00	5.50	10	100.00	50.50

Table 2 - One-way and Total Outage Scale Factors vs Fade Margin Reduction